

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner
 US Department of Commerce
 United States Patent and Trademark
 Office, PCT
 2011 South Clark Place Room
 CP2/5C24
 Arlington, VA 22202
 ETATS-UNIS D'AMERIQUE
 in its capacity as elected Office

Date of mailing (day/month/year) 14 February 2001 (14.02.01)	
International application No. PCT/DK00/00227	Applicant's or agent's file reference 17503 PCT
International filing date (day/month/year) 04 May 2000 (04.05.00)	Priority date (day/month/year) 17 May 1999 (17.05.99)
Applicant RASMUSSEN, Claus, Nygaard et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:
 13 December 2000 (13.12.00)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer F. Baechler Telephone No.: (41-22) 338.83.38
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PCT

From the INTERNATIONAL BUREAU

**NOTIFICATION OF THE RECORDING
 OF A CHANGE**

(PCT Rule 92bis.1 and
 Administrative Instructions, Section 422)

To:

LARSEN & BIRKEHOLM A/S
 Skandinavisk Patentbureau
 Banegårdspladsen 1
 P.O. Box 362
 DK-1570 København V
 DANEMARK

Date of mailing (day/month/year)
 14 February 2001 (14.02.01)

Applicant's or agent's file reference
 17503 PCT

International application No.
 PCT/DK00/00227

IMPORTANT NOTIFICATION

International filing date (day/month/year)
 04 May 2000 (04.05.00)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address

NKT RESEARCH A/S
 Priorparken 878
 DK-2605 Brøndby
 Denmark

State of Nationality

State of Residence

Telephone No.

45 4348 3500

Facsimile No.

45 4363 0099

Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☒ the person ☒ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address

LARSEN & BIRKEHOLM A/S
 Skandinavisk Patentbureau
 Banegårdspladsen 1
 P.O. Box 362
 DK-1570 København V
 Denmark

State of Nationality

State of Residence

Telephone No.

+45 33 13 09 30

Facsimile No.

+45 33 13 09 34

Teleprinter No.

3. Further observations, if necessary:

Please note that the agent's file reference has changed as well.

4. A copy of this notification has been sent to:

☒ the receiving Office ☐ the designated Offices concerned
☐ the International Searching Authority ☒ the elected Offices concerned
☒ the International Preliminary Examining Authority ☐ other:

The International Bureau of WIPO
 34, chemin des Colombettes
 1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

F. Baechler

Telephone No.: (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference RESE PA 9902 WO	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/DK 00/ 00227	International filing date (day/month/year) 04/05/2000	(Earliest) Priority Date (day/month/year) 17/05/1999
Applicant NKT RESEARCH A/S		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.



the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :



contained in the international application in written form.



filed together with the international application in computer readable form.



furnished subsequently to this Authority in written form.



furnished subsequently to this Authority in computer readable form.



the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.



the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,



the text is approved as submitted by the applicant.



the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,



the text is approved as submitted by the applicant.



the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.



as suggested by the applicant.



because the applicant failed to suggest a figure.



because this figure better characterizes the invention.

2



None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No

P K 00/00227

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02H9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01B H01H H02H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section EI, Week 198151 Derwent Publications Ltd., London, GB; Class X12, AN 1981-N0515D XP002901245 & SU 809 405 B (KRZHIZHANOV POWER), 8 March 1981 (1981-03-08) abstract	1-14
X	--- PATENT ABSTRACTS OF JAPAN vol. 013, no. 232 (E-765), 29 May 1989 (1989-05-29) & JP 01 039230 A (MITSUBISHI ELECTRIC CORP), 9 February 1989 (1989-02-09) abstract --- -/--	1-14

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

14 September 2000

Date of mailing of the international search report

20. 11. 00

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Bertil Nordenberg

INTERNATIONAL SEARCH REPORT

International Application No

PCT/K 00/00227

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DD 126 232 A (INSTITUT, PRÜFFELD FÜR ELEKTRISCHE HOCHLEISTUNGSTECHNIK) 6 July 1977 (1977-07-06) abstract; figures 1-3 ---	1-14
A	DATABASE WPI Section EI, Week 199309 Derwent Publications Ltd., London, GB; Class X12, AN 1993-073656 XP002901246 & JP 05 022856 A (MITSUBISHI ELECTRIC CORP), 29 January 1993 (1993-01-29) abstract ---	4,12
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 374 (E-808), 18 August 1989 (1989-08-18) & JP 01 126132 A (NIPPON KOUATSU ELECTRIC CO), 18 May 1989 (1989-05-18) abstract ---	5,13
A	WO 96 22258 A (UNIVERSITY OF HAWAII) 25 July 1996 (1996-07-25) page 4, line 3 - line 8 -----	11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/K 00/00227

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
SU 809405	B	08-03-1981	SU 714510 A	07-02-1980
JP 01039230	A	09-02-1989	NONE	
DD 126232	A	06-07-1977	DE 2712990 A	29-12-1977
JP 5022856	A	29-01-1993	NONE	
JP 01126132	A	18-05-1989	NONE	
WO 9622258	A	25-07-1996	US 5591698 A	07-01-1997
			AU 4743796 A	07-08-1996
			EP 0800494 A	15-10-1997
			JP 10511926 T	17-11-1998

2/p1s

1

A method for overcurrent protection in a superconducting cable.

The invention relates to a method for overcurrent protection in a superconducting cable.

5

Furthermore, the invention relates to a superconducting cable.

10

When using superconducting cables in a high-voltage system, it is important that said cables are protected from overcurrents since the result of overcurrents in the cable conductor of a superconducting cable is loss of superconductivity thereof. This means that the cable could soon be exposed to destruction, since the superconducting tapes conducting the current are not at all adapted to transmit large currents, when they are not superconducting.

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A typical requirement for a superconducting cable is that it should be protected from overcurrents.

This protection requirement may e.g. be that the cable should be able to withstand approximately 40 kA for 1 second.

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The object of the invention is now to provide a method for protecting a superconducting cable, accommodating the requirements stipulated above.

25

The objective of the invention is fulfilled by a method of the type defined in the preamble of claim 1, the method being characterized in that a current detector, which can be constituted by a part of or all of the cable, is inserted in series with the cable conductor of the superconducting cable.

30

Hence, constant monitoring of the current in the superconducting cable during operation is ensured, so that if the current exceeds some predetermined limits, the current will be broken or limited prior to a destructive, heavy heating of the cable.

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By the insertion, as indicated in claim 2, of at least one superconducting piece as current detector, reliable overcurrent detection is obtained, since the superconducting pieces - if exposed to a current that is too high - exit their superconducting state, causing an intense generation of heat in the superconducting pieces.

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NO.: EV 011019060 US

This generation of heat can then be used if, as indicated in claim 3, a fuse is inserted as a circuit breaker to break the current to the cable conductors of the superconducting cable.

5 With a view to accommodating the time delay in a circuit breaker, specifically the inevitable time delay defined by the period of time necessary for breaking a current by means of a circuit breaker, it is advantageous, as indicated in claim 4, to insert a cold shunt in parallel with the cable conductors of the superconducting cable, the cold shunt being designed to be capable of carrying e.g. 40kA in 0.1 second.

10

For diversion of the current to the superconducting cable after the above-mentioned 0.1 second has elapsed, an electrical conductor is preferably inserted, as indicated in claim 5, in parallel with the cable conductor of the cable and the current detector, said electrical conductor having a higher impedance than the superconducting cable

15

when in its superconducting state.

Thus, when the superconducting state ceases, the current is allowed to be diverted in the hot shunt.

Additional appropriate embodiments of the method are set out in claims 6-8.

20

As already mentioned, the invention also relates to a superconducting cable.

This cable is of the type defined in the preamble of claim 9 and is characterised in that the cable conductor of the cable is connected in series with a current detector

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for detecting overcurrents and a circuit breaker or a current limiter.

Appropriate embodiments of the cable are set out in the independent claims 8-14.

In the following, the invention will be discussed in greater detail with reference to an

30

exemplary embodiment shown in the drawings in which:

Fig. 1 shows a basic construction of a superconducting cable with overcurrent protection according to the invention,

35 Fig. 2 shows a more detailed construction of an embodiment of the cable with overcurrent protection according to the invention,

Fig. 3 shows the relationship with respect to time between currents flowing in the cable according to Fig. 2 in an overcurrent situation, whereas

- 5 Fig. 4 shows in perspective and partially intersected a superconducting cable with overcurrent protection according to the invention.

10 In Fig. 1 a superconducting cable is denoted by 1, said superconducting cable possibly, as known in the art, being constructed of a core, around which one or more layers of superconducting tapes is/are wound.

Current detectors 3, 4 are coupled to the ends of the cable, the current detectors having built-in circuit breakers or current limiters.

15 The current detectors may e.g. comprise superconducting pieces such as YBCO or Bi 2212 with built-in circuit breakers, and may be dimensioned such that they quench at a lower current than the superconductor of the actual cable, implying that if the current in the superconducting pieces exceeds a certain value, then the current to the superconducting cable will be broken after a short period of time.

By use of current limiters, the current will naturally be limited.

20 A hot shunt is coupled in parallel with a series connection of the superconducting pieces and the cable conductors of the superconducting cable, said shunt being capable of diverting the current supplied for a short period of time if the current detectors break the current or the current limiter limits the current.

25 Fig. 2 shows a more detailed embodiment of the superconducting cable according to the invention.

In this figure, 13 denotes current detectors corresponding to those denoted by 3 and 4 in Fig. 1.

30 The reference number 7 denotes a superconducting cable corresponding to the cable 1 of Fig. 1. A cold shunt is provided in parallel with the cable conductors of the cable, the shunt being denoted by the reference number 11. This shunt is cooled to the temperature of the superconductor. On the outside of this cold shunt is a cryostat 8, and on the outside thereof is an electrical insulation 9.

35 On the inside of the electrical insulation 9, an electrical conductor 10 is provided, which is made e.g. of copper and serves as a hot shunt at ambient temperature, cf. below.

The operation of the current detector in the superconducting cable will now be explained in greater detail with reference to the current plot of Fig. 3.

- 5 If it is ascertained that a current, which is too high, is flowing in the superconducting pieces 3, 4 or 13, the current will in a short time period flow in the cold shunt 11.

Then the current will be fed to the hot shunt 10, wherein the current will increase steeply as indicated by the broken line in Fig. 3 at the time 0.1s. At the same time,
10 the current in the cold shunt 11 will decrease steeply.

Damage to the superconducting cable in the event that its superconductivity ceases can thus be avoided, which means that it becomes ohmic and consequently not capable of conducting the usual currents that can be conducted in the superconducting
15 state.

Fig. 4 shows in perspective and partially intersected a superconducting cable as occurring in actual practice, which can be used in connection with the current protection as explained in connection with the preceding figures.

20

In this figure, 12 denotes a shield on the outside of which is a jacket 14. Inside the jacket is a dielectric insulator 15 surrounding an outer steel tube 16.

Inside the steel tube 16, spacers 17 are arranged that are supported by an aluminium foil 18 abutting an inner steel tube 19.

- 25 Inside the inner steel tube 19 a number of superconducting tapes 20 are wound around a hollow core 21.

The cooling of the superconducting tapes can be effected by supplying refrigerant to the channel 22 of the hollow core.

- 30 The reference number 23 denotes the position in which the cold shunt can be placed as explained above, whereas the reference number 24 denotes the position within the dielectric insulator, where the hot shunt can be placed.

C l a i m s :

1. A method for overcurrent protection in a superconducting cable,
5 c h a r a c t e r i z e d in that a current detector, which can be constituted by a part of
or all of the cable, is inserted in series with the cable conductor of the
superconducting cable.
2. A method according to claim 1, c h a r a c t e r i z e d in that at least one super-
10 conducting piece is inserted as the current detector.
3. A method according to claim 1 or 2, c h a r a c t e r i z e d in that a fuse is inserted
as the circuit breaker.
- 15 4. A method according to any of claims 1-3, c h a r a c t e r i z e d in that a cold
shunt is inserted in parallel with the cable conductors of the superconducting cable.
5. A method according to any of claims 1-4, c h a r a c t e r i z e d in that an electri-
cal conductor is inserted in parallel with the cable conductors of the superconducting
20 cable and the current detector or current limiter, said electrical conductor having a
higher impedance than the superconducting cable when in its superconducting
state.
6. A method according to any of claims 1-6, c h a r a c t e r i z e d in that a material
25 comprising a superconducting material quenching at a lower current than the super-
conducting cable is inserted as the current detector.
7. A method according to any of claims 1-6, c h a r a c t e r i z e d in that the current
detector comprises a relay or a fuse, a thyristor, a transistor, or similar power elec-
30 tronic components.
8. A method according to any of claims 1-7, c h a r a c t e r i z e d in that the current
detector is constituted by a current-dependent resistance.

9. A superconducting cable characterized in that the cable conductors of the cable are connected in series with a current detector for overcurrent detection and a circuit breaker or current limiter.

5 10. A superconducting cable according to claim 9, characterized in that the circuit breaker comprises a fuse.

10 11. A superconducting cable according to claim 8 or 9, characterized in that the current detector is constituted by a superconducting material such as YBCO or Bi₂212.

15 12. A superconducting cable according to any of claims 8-11, characterized in that a cold shunt is coupled in parallel with the cable conductor of the cable. The cold shunt is wound in such a way that the current in this is reduced to a minimum during normal operation.

20 13. A superconducting cable according to any of claims 10-12, characterized in that a shunt at ambient temperature is coupled in parallel with the superconducting material of the superconducting cable, and the current detector.

14. A superconducting cable according to claim 9, characterized in that the circuit breaker comprises high-speed power electronics.

A method for overcurrent protection in a superconducting cable.

ABSTRACT

5 By a method and a superconducting cable for overcurrent protection, a current detector comprising a circuit breaker or a current limiter is inserted in series with the superconducting cable, which current detector can be constituted by a superconducting material quenching at a lower current than the cable conductor of the superconducting cable.

10 When the current in the superconducting material gets too high, it is for a short time period fed to a cold shunt that is coupled in parallel with the cable conductors of the superconducting cable. After the short time period, the current is fed to a hot shunt that is coupled in parallel outside the cable conductors of the cable, causing heat dissipation to be effected at room temperature.

15

By use of the method and the cable according to the invention, destruction of the cable is prevented should the superconducting cable lose its superconductivity, e.g. due to cooling failure, whereupon normal operation may soon be resumed without restoration of damages being necessary.

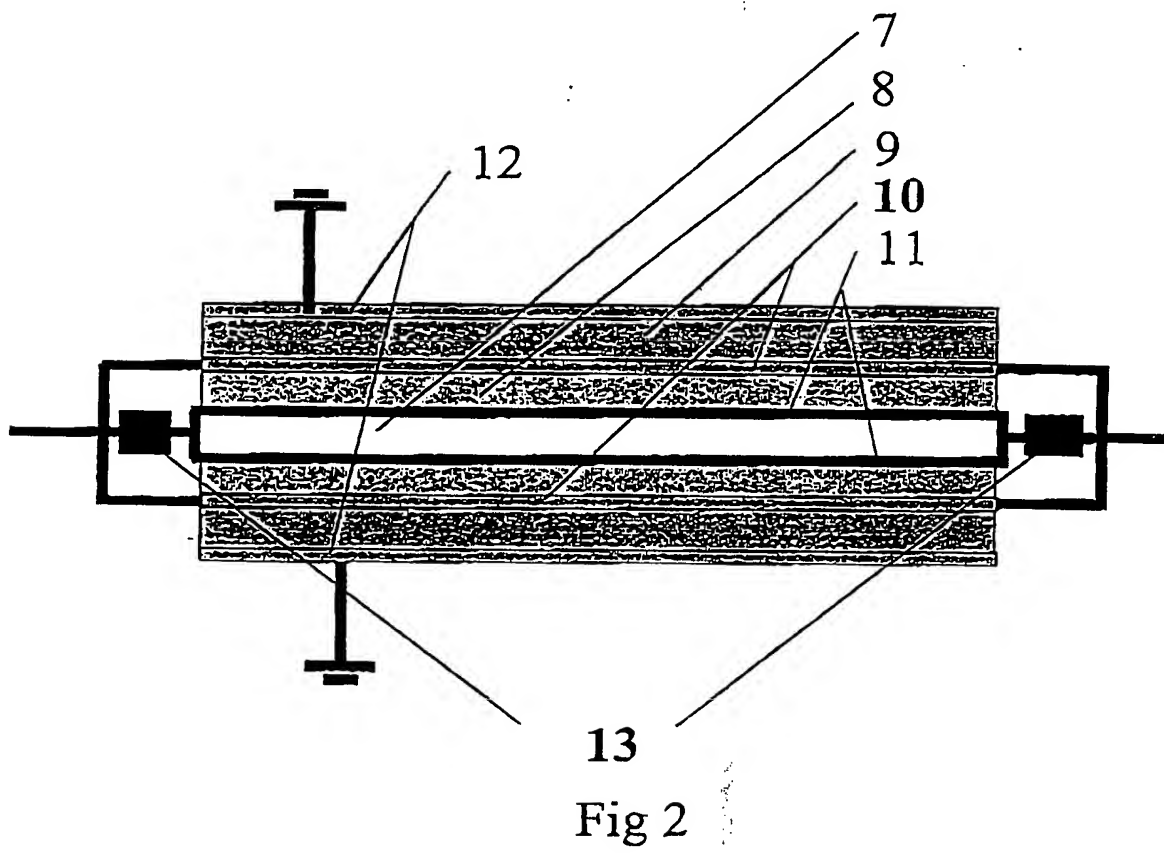
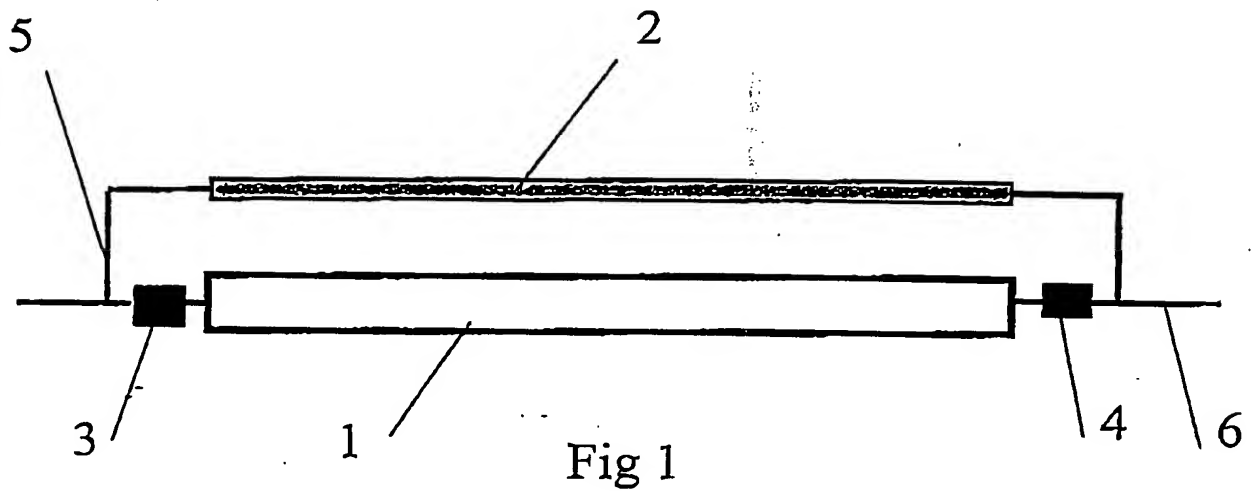
20

It is proposed that Fig. 2 be published.

25

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35



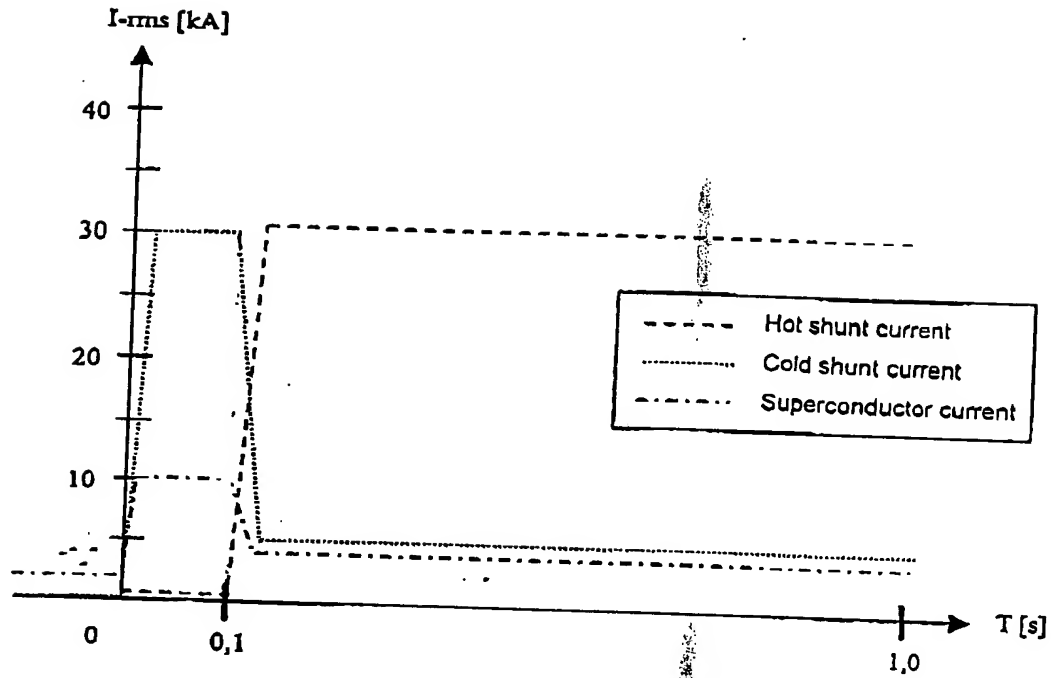


Fig 3

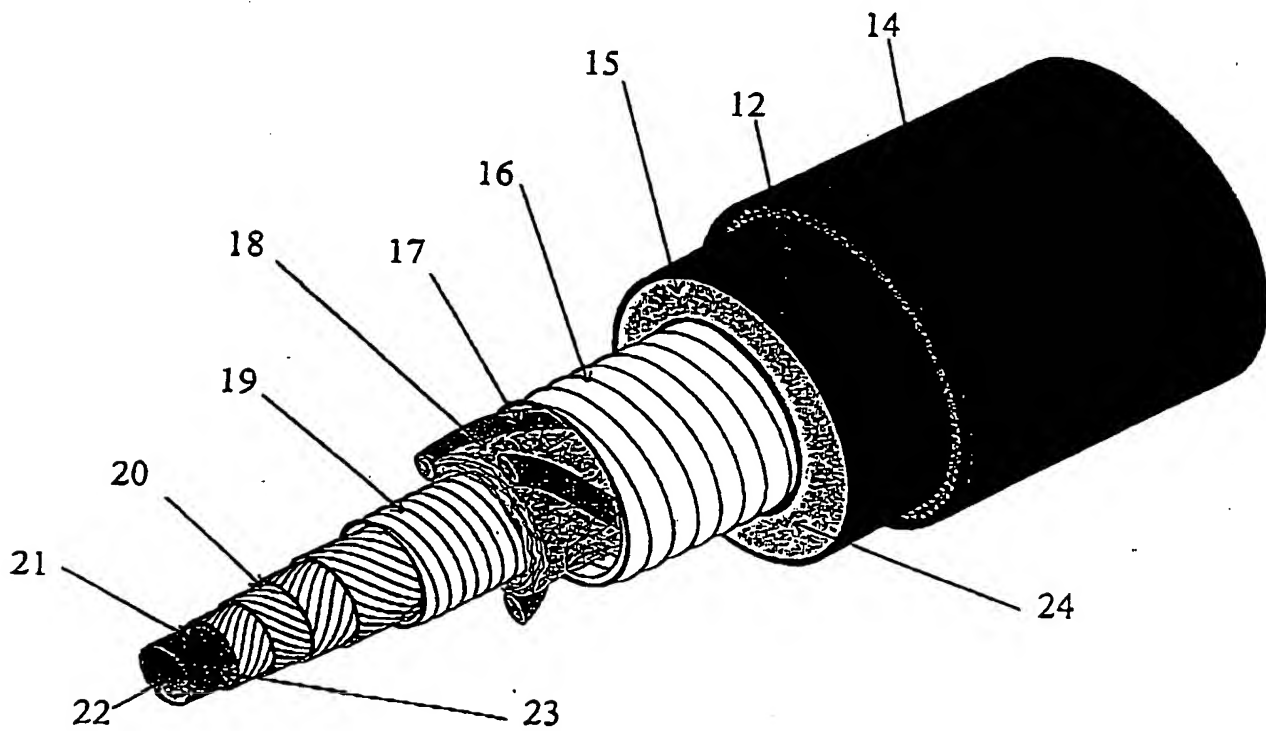


Fig 4

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

Applicant's or agent's file reference 17503 PCT	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/DK 00/ 00227	International filing date (day/month/year) 04/05/2000	Priority date (day/month/year) 17/05/1999
International Patent Classification (IPC) or national classification and IPC H02H9/02		
Applicant NKT RESEARCH A/S		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.


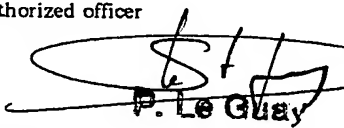
2. This REPORT consists of a total of 4 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consists of a total of 9 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand 13/12/2000	Date of completion of this report 11.09.01
Name and mailing address of the IPEA/  European Patent Office D-80298 Munich Tel. (+49-89) 2399-0, Tx: 523656 epmu d Fax: (+49-89) 2399-4465	Authorized officer  P. Le Guay



INTERNATIONAL PRELIMINARY EXAMINATION REPORT

I. Basis of the report

1. This report has been drawn up on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*

☒ the international application as originally filed

☒ the description, pages , as originally filed
 pages , filed with the demand
 pages 1-5 , filed with the letter of 06.07.01

☒ the claims, Nos. , as originally filed
 Nos. , as amended under Article 19
 Nos. , filed with the demand
 Nos. 1-14 , filed with the letter of 06.07.01

☒ the drawings, sheets / fig. , as originally filed
 sheets / fig. , filed with the demand
 sheets / fig. 1/2-2/2 , filed with the letter of 06.07.01

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
☐ the claims, Nos.
☐ the drawings, sheets / fig.

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2 (c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Claims	1-14	YES
	Claims	None	NO
Inventive Step	Claims	None	YES
	Claims	1-14	NO
Industrial Applicability	Claims	1-14	YES
	Claims	None	NO

2. Citations and Explanations

1. Concerning claim 1:

Document JP-A-01039230 discloses a method for protecting a superconducting cable against overcurrent by inserting a current detector (second superconducting wire 11) in series with the cable conductor (see abstract and figure). Moreover document JP-A-01126132 discloses a resistor (4) which is inserted in parallel with a superconductor (3) and a current-limiting element (1).

As any conductor has a certain resistance, the resistance (4) of JP'132 can be considered as a resistance.

Therefore a combination of both cited documents would lead to a method according to claim 1 which lacks inventive step in terms of Article 33(3) PCT.

2. The same applies for claim 9 which discloses a superconducting cable corresponding to the method of claim 1.
3. The additional subject-matter disclosed in dependent claims 2 to 8 and 10 to 14 is either known from the other documents cited in the search report or easily available to the skilled person.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

It is therefore assumed that claims 2 to 8 and 10 to 14 lack an inventive step
(Article 33(3) PCT).

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 17503 PCT	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/DK 00/ 00227	International filing date (day/month/year) 04/05/2000	Priority date (day/month/year) 17/05/1999
International Patent Classification (IPC) or national classification and IPC H02H9/02		
Applicant NKT RESEARCH A/S		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This **REPORT** consists of a total of 4 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consists of a total of 9 sheets.

3. This report contains indications relating to the following items:

I ☒ Basis of the report

II ☐ Priority

III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability


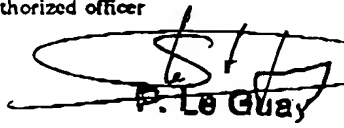

IV ☐ Lack of unity of invention

V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

VI ☐ Certain documents cited

VII ☐ Certain defects in the international application

VIII ☐ Certain observations on the international application

Date of submission of the demand 13/12/2000	Date of completion of this report 11.09.01
Name and mailing address of the (IPEA/  European Patent Office D-80298 Munich Tel. (+49-89) 2399-0, Tx: 523656 epmu d Fax: (+49-89) 2399-4465	Authorized officer  P. Le Guay 

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

I. Basis of the report

1. This report has been drawn up on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*

☒ the international application as originally filed

<input checked="" type="checkbox"/> the description, pages		, as originally filed	
	pages	, filed with the demand	
	pages 1-5	, filed with the letter of	06.07.01

<input checked="" type="checkbox"/> the claims, Nos.		, as originally filed	
	Nos.	, as amended under Article 19	
	Nos.	, filed with the demand	
	Nos. 1-14	, filed with the letter of	06.07.01

<input checked="" type="checkbox"/> the drawings, sheets / fig.		, as originally filed	
	sheets / fig.	, filed with the demand	
	sheets / fig. 1/2-2/2	, filed with the letter of	06.07.01

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.
- ☐ the drawings, sheets / fig.

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2 (c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Claims	1-14	YES
	Claims	None	NO
Inventive Step	Claims	None	YES
	Claims	1-14	NO
Industrial Applicability	Claims	1-14	YES
	Claims	None	NO

2. Citations and Explanations

1. Concerning claim 1:

Document JP-A-01039230 discloses a method for protecting a superconducting cable against overcurrent by inserting a current detector (second superconducting wire 11) in series with the cable conductor (see abstract and figure). Moreover document JP-A-01126132 discloses a resistor (4) which is inserted in parallel with a superconductor (3) and a current-limiting element (1).

As any conductor has a certain resistance, the resistance (4) of JP'132 can be considered as a resistance.

Therefore a combination of both cited documents would lead to a method according to claim 1 which lacks inventive step in terms of Article 33(3) PCT.

2. The same applies for claim 9 which discloses a superconducting cable corresponding to the method of claim 1.
3. The additional subject-matter disclosed in dependent claims 2 to 8 and 10 to 14 is either known from the other documents cited in the search report or easily available to the skilled person.

International application No.

PCT/DK00/00227

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

It is therefore assumed that claims 2 to 8 and 10 to 14 lack an inventive step
(Article 33(3) PCT).

Amended description and Claims

PCT/DK00/00227

A method for overcurrent protection in a superconducting cable.

- 5 The invention relates to a method for overcurrent protection in a superconducting cable, comprising a current detector, which is inserted in series with the cable conductor of the superconducting cable

Furthermore, the invention relates to a superconducting cable, wherein the cable
10 conductors of the cable are connected in series with a current detector for overcurrent detection.

When using superconducting cables in a high-voltage system, it is important that said cables are protected from overcurrents since the result of overcurrents in the
15 cable conductor of a superconducting cable is loss of superconductivity thereof. This means that the cable could soon be exposed to destruction, since the superconducting tapes conducting the current are not at all adapted to transmit large currents, when they are not superconducting.

- 20 A typical requirement for a superconducting cable is that it should be protected from overcurrents.

This protection requirement may e.g. be that the cable should be able to withstand approximately 40 kA for 1 second.

- 25 JP 01 039230 discloses a method for protecting a superconducting cable against overcurrent by inserting a current detector in series with the cable conductor.

The object of the invention is now to provide a method for protecting a superconducting cable, accommodating the requirements stipulated above.

30

The objective of the invention is fulfilled by a method of the type defined in the preamble of claim 1, the method being characterized in that an electrical conductor is inserted in parallel with the cable conductors of the superconducting cable and the current detector.

35

Hence, constant monitoring of the current in the superconducting cable during operation is ensured, so that if the current exceeds some predetermined limits, the current will be broken or limited prior to a destructive, heavy heating of the cable.

Thus, when the superconducting state ceases, the current is allowed to be diverted
5 in the hot shunt.

As indicated in claim 4, that the current detector constitutes at least one superconducting piece, reliable overcurrent detection is obtained, since the superconducting pieces - if exposed to a current that is too high - exit their
10 superconducting state, causing an intense generation of heat in the superconducting pieces.

This generation of heat can then be used if, as inter alia indicated in claim 6, a fuse is inserted as a circuit breaker to break the current to the cable conductors of the
15 superconducting cable.

With a view to accommodating the time delay in a circuit breaker, specifically the inevitable time delay defined by the period of time necessary for breaking a current by means of a circuit breaker, it is advantageous, as indicated in claim 8, to a cold
20 shunt is inserted in parallel with the cable conductors of the superconducting cable. The cold could be designed to be capable of carrying e.g. 40kA in 0.1 second.

It is noted that the for diversion of the current to the superconducting cable after the above-mentioned 0.1 second has elapsed, then the electrical conductor is
25 preferably inserted.

Additional appropriate embodiments of the method are set out in claims 2,3,5 and 7.

30 As already mentioned, the invention also relates to a superconducting cable wherein the cable conductors of the cable are connected in series with a current detector for overcurrent detection

This cable is of the type defined in the preamble of claim 9 and is characterised in that an electrical conductor is inserted in parallel with the cable conductors of the superconducting cable and the current detector.

5 Appropriate embodiments of the cable are set out in the independent claims 10-14.

In the following, the invention will be discussed in greater detail with reference to an exemplary embodiment shown in the drawings in which:

10 Fig. 1 shows a basic construction of a superconducting cable with overcurrent protection according to the invention,

Fig. 2 shows a more detailed construction of an embodiment of the cable with overcurrent protection according to the invention,

15

Fig. 3 shows the relationship with respect to time between currents flowing in the cable according to Fig. 2 in an overcurrent situation, whereas

Fig. 4 shows in perspective and partially intersected a superconducting cable with
20 overcurrent protection according to the invention.

In Fig. 1 a superconducting cable is denoted by 1, said superconducting cable possibly, as known in the art, being constructed of a core, around which one or more layers of superconducting tapes is/are wound.

25

Current detectors 3, 4 are coupled to the ends of the cable, the current detectors having built-in circuit breakers or current limiters.

The current detectors may e.g. comprise superconducting pieces such as YBCO or Bi 2212 with built-in circuit breakers, and may be dimensioned such that they
30 quench at a lower current than the superconductor of the actual cable, implying that if the current in the superconducting pieces exceeds a certain value, then the current to the superconducting cable will be broken after a short period of time.

By use of current limiters, the current will naturally be limited.

A hot shunt is coupled in parallel with a series connection of the superconducting
35 pieces and the cable conductors of the superconducting cable, said shunt being ca-

pable of diverting the current supplied for a short period of time if the current detectors break the current or the current limiter limits the current.

Fig. 2 shows a more detailed embodiment of the superconducting cable according to the invention.

In this figure, 3,4 again denotes current and the reference number 7 denotes a superconducting cable.

A cold shunt is provided in parallel with the cable conductors of the cable, the shunt being denoted by the reference number 11. This shunt is cooled to the temperature of the superconductor. On the outside of this cold shunt is a cryostat 8, and on the outside thereof is an electrical insulation 9.

On the inside of the electrical insulation 9, an electrical conductor 10 is provided, which is made e.g. of copper and serves as a hot shunt at ambient temperature, cf. below.

15

The operation of the current detector in the superconducting cable will now be explained in greater detail with reference to the current plot of Fig. 3.

If it is ascertained that a current, which is too high, is flowing in the superconducting pieces 3, 4 the current will in a short time period flow in the cold shunt 11.

Then the current will be fed to the hot shunt 10, wherein the current will increase steeply as indicated by the broken line in Fig. 3 at the time 0.1s. At the same time, the current in the cold shunt 11 will decrease steeply.

25

Damage to the superconducting cable in the event that its superconductivity ceases can thus be avoided, which means that it becomes ohmic and consequently not capable of conducting the usual currents that can be conducted in the superconducting state.

30

Fig. 4 shows in perspective and partially intersected a superconducting cable as occurring in actual practice, which can be used in connection with the current protection as explained in connection with the preceding figures:

In this figure, 12 denotes a shield on the outside of which is a jacket 14. Inside the jacket is a dielectric insulator 15 surrounding an outer steel tube 16.

Inside the steel tube 16, spacers 17 are arranged that are supported by an aluminium foil 18 abutting an inner steel tube 19.

- 5 Inside the inner steel tube 19 a number of superconducting tapes 1 are wound around a hollow core 21.

The cooling of the superconducting tapes can be effected by supplying refrigerant to the channel 22 of the hollow core.

- 10 The reference number 11 denotes the position in which the cold shunt can be placed as explained above, whereas the reference number 24 denotes the position within the dielectric insulator, where the hot shunt can be placed.

Claims:

PCT/DK00/00227

- 5 1. A method for overcurrent protection in a superconducting cable, comprising a current detector (3,4), which is inserted in series with the cable conductor of the superconducting cable, c h a r a c t e r i z e d in that an electrical conductor (10) is inserted in parallel with the cable conductors of the superconducting cable (1) and the current detector (3,4).
- 10 2. A method according to claim 1 c h a r a c t e r i z e d in that the electrical conductor (10) has a higher impedance than the superconducting cable (1) when in its superconducting state.
- 15 3. A method according to claim 1 - 2, c h a r a c t e r i z e d in that the electrical conductor (10) is placed outside a cryostat (8) of the superconducting cable (1).
- 20 4. A method according to claim 1 - 3, c h a r a c t e r i z e d in that the current detector (3,4) constitutes at least one superconducting piece.
- 25 5. A method according to any of claims 1 - 4, c h a r a c t e r i z e d in that the current detector (3,4) comprises a superconducting material which quenches at a lower current than the superconducting cable (7).
- 30 6. A method according to any of claims 1-5, c h a r a c t e r i z e d in that the current detector (3,4) comprises a relay or a circuit breaker e.q. fuse, a thyristor, a transistor, or similar power electronic components.
- 35 7. A method according to any of claims 1-6, c h a r a c t e r i z e d in that the current detector (3,4) is constituted by a current-dependent resistance.
8. A method according to any of claims 1 - 7, c h a r a c t e r i z e d in that a cold shunt (11) is inserted in parallel with the cable conductors of the superconducting cable (7).

5 9. A superconducting cable (1) wherein the cable conductors of the cable are connected in series with a current detector (3,4) for overcurrent detection, characterized in that an electrical conductor (10) is inserted in parallel with the cable conductors of the superconducting cable (1) and the current detector (3,4).

10 10. A superconducting cable according to claim 9, characterized in that the electrical conductor (10) has a higher impedance than the superconducting cable (1) when in its superconducting state.

11. A superconducting cable according to claim 9 or 10, characterized in that the electrical conductor (10) is placed outside a cryostat (8) of the superconducting cable.

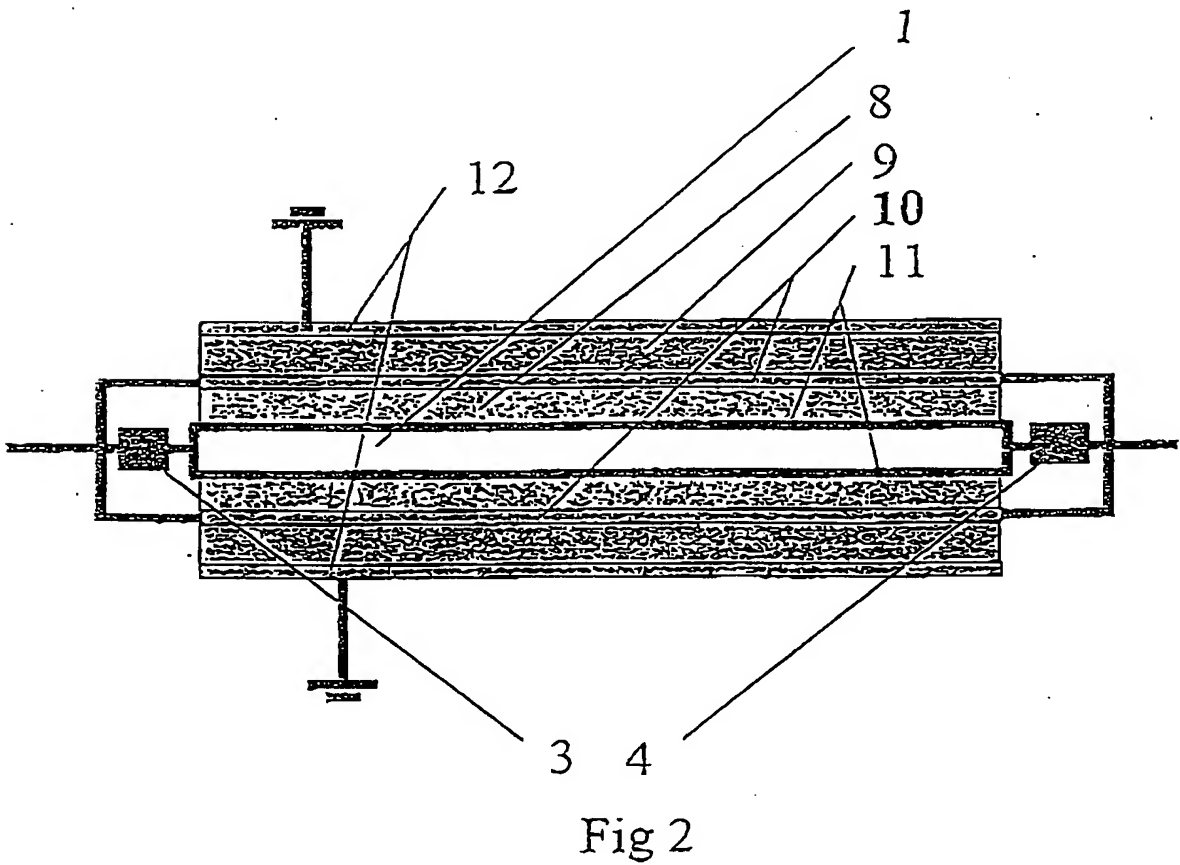
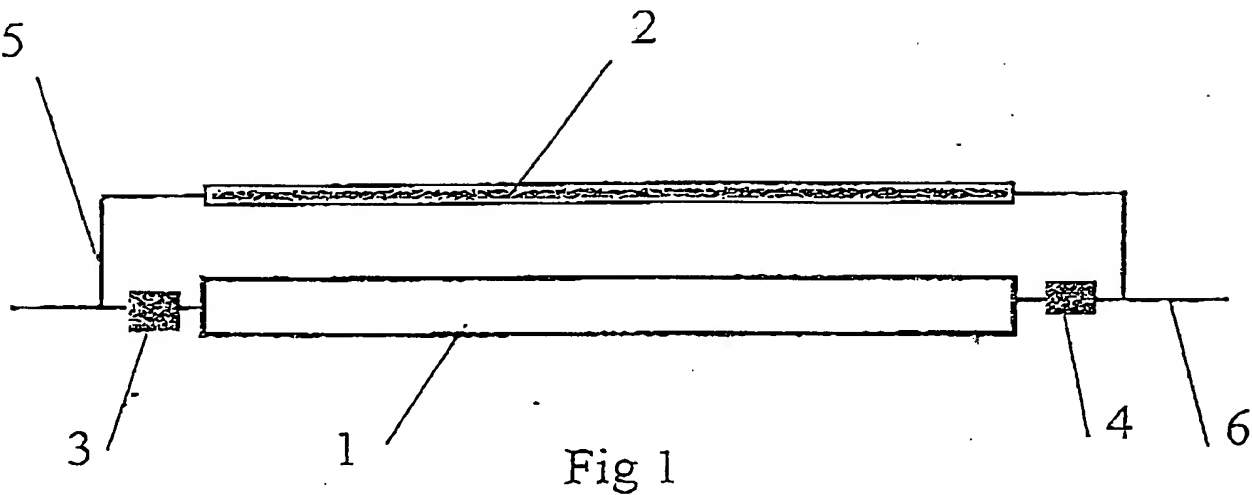
15 12. A superconducting cable according to claim 11 characterized in that the cold shunt (8) is wound in such a way that the current in this is reduced to a minimum during normal operation.

20 13. A superconducting cable according to claim 9 - 12, characterized in that the current detector (3,4) comprises a circuit breaker or a current limiter, and that the circuit breaker comprises a fuse and/or high-speed power electronics.

25 14. A superconducting cable according to claim 9 - 13, characterized in that the current detector is constituted by a superconducting material such as YBCO or Bi 2212.

30

1/2



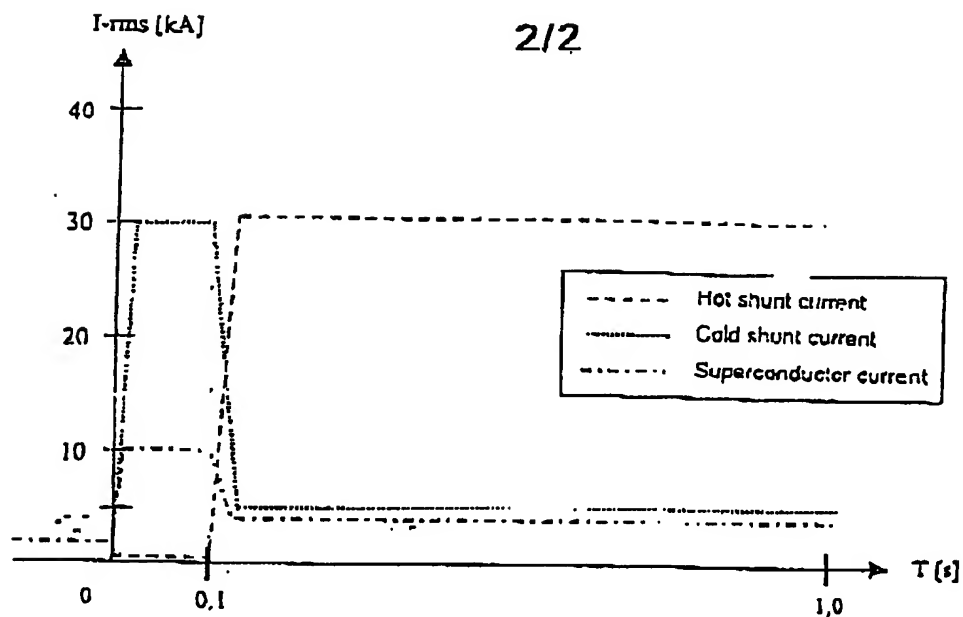


Fig 3

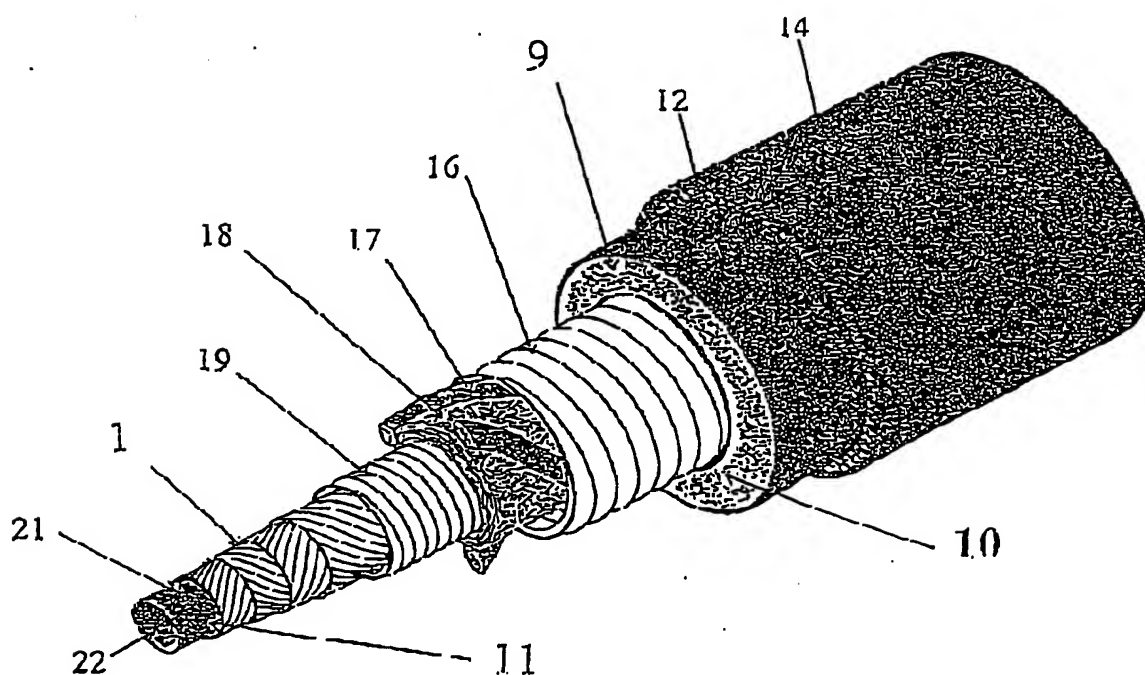


Fig 4

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving use only

U 013710-8

International Application No.

10/009227

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference RESE PA 9902 WO
(if desired) (12 characters maximum)

Box No. I TITLE OF INVENTION

A method for overcurrent protection in a superconducting cable.

Box No. II APPLICANT

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

NKT Research A/S
Priorparken 878
DK-2605 Brøndby
Denmark

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State (that is, country) of nationality:
DenmarkState (that is, country) of residence:
Denmark

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

Rasmussen Claus Nygaard
Knivholtvej 16, 1. tv.
DK-2720 Vanløse
Denmark

This person is:

☐ applicant only☒ applicant and inventor☐ inventor only (If this check-box is marked, do not fill in below.)State (that is, country) of nationality:
DenmarkState (that is, country) of residence:
Denmark

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:

☒ agent☐ common representative

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)
NKT Research A/S
Priorparken 878
DK-2605 Brøndby
Denmark

Telephone No.

+45 4348 3500

Facsimile No.

+45 4363 0099

Teleprinter No.

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

EXPRESS MAIL LABEL

NO.: EV 011019060 US

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

Nielsen Jørgen Nygård
Lavendelhaven 75
DK-2830 Virum
Denmark

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

Denmark

State (that is, country) of residence:

Denmark

This person is applicant for the purposes of:

☐ all designated States☐ all designated States except the United States of America☒ the United States of America only☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

Østergaard Jens Jacob
C. T. Barfodvej 11, 1. tv.
DK-2000 Frederiksberg
Denmark

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

Denmark

State (that is, country) of residence:

Denmark

This person is applicant for the purposes of:

☐ all designated States☐ all designated States except the United States of America☒ the United States of America only☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

☐ all designated States☐ all designated States except the United States of America☐ the United States of America only☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

☐ all designated States☐ all designated States except the United States of America☐ the United States of America only☐ the States indicated in the Supplemental Box☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No. V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) (mark the applicable check-boxes; at least one must be marked):

Regional Patent

- ☒ AP ARIPO Patent: GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☒ EA Eurasian Patent: AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ EP European Patent: AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ OA OAPI Patent: BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT (if other kind of protection or treatment desired, specify on dotted line)

National Patent (if other kind of protection or treatment desired, specify on dotted line):

- | | |
|--|--|
| <input checked="" type="checkbox"/> AE United Arab Emirates | <input checked="" type="checkbox"/> LR Liberia |
| <input checked="" type="checkbox"/> AL Albania | <input checked="" type="checkbox"/> LS Lesotho |
| <input checked="" type="checkbox"/> AM Armenia | <input checked="" type="checkbox"/> LT Lithuania |
| <input checked="" type="checkbox"/> AT Austria and Utility Model | <input checked="" type="checkbox"/> LU Luxembourg |
| <input checked="" type="checkbox"/> AU Australia | <input checked="" type="checkbox"/> LV Latvia |
| <input checked="" type="checkbox"/> AZ Azerbaijan | <input checked="" type="checkbox"/> MD Republic of Moldova |
| <input checked="" type="checkbox"/> BA Bosnia and Herzegovina | <input checked="" type="checkbox"/> MG Madagascar |
| <input checked="" type="checkbox"/> BB Barbados | <input checked="" type="checkbox"/> MK The former Yugoslav Republic of Macedonia |
| <input checked="" type="checkbox"/> BG Bulgaria | |
| <input checked="" type="checkbox"/> BR Brazil | <input checked="" type="checkbox"/> MN Mongolia |
| <input checked="" type="checkbox"/> BY Belarus | <input checked="" type="checkbox"/> MW Malawi |
| <input checked="" type="checkbox"/> CA Canada | <input checked="" type="checkbox"/> MX Mexico |
| <input checked="" type="checkbox"/> CH and LI Switzerland and Liechtenstein | <input checked="" type="checkbox"/> NO Norway |
| <input checked="" type="checkbox"/> CN China | <input checked="" type="checkbox"/> NZ New Zealand |
| <input checked="" type="checkbox"/> CU Cuba | <input checked="" type="checkbox"/> PL Poland |
| <input checked="" type="checkbox"/> CZ Czech Republic and Utility Model | <input checked="" type="checkbox"/> PT Portugal |
| <input checked="" type="checkbox"/> DE Germany and Utility Model | <input checked="" type="checkbox"/> RO Romania |
| <input checked="" type="checkbox"/> DK Denmark and Utility Model | <input checked="" type="checkbox"/> RU Russian Federation |
| <input checked="" type="checkbox"/> EE Estonia and Utility Model | <input checked="" type="checkbox"/> SD Sudan |
| <input checked="" type="checkbox"/> ES Spain | <input checked="" type="checkbox"/> SE Sweden |
| <input checked="" type="checkbox"/> FI Finland and Utility Model | <input checked="" type="checkbox"/> SG Singapore |
| <input checked="" type="checkbox"/> GB United Kingdom | <input checked="" type="checkbox"/> SI Slovenia |
| <input checked="" type="checkbox"/> GD Grenada | <input checked="" type="checkbox"/> SK Slovakia and Utility Model |
| <input checked="" type="checkbox"/> GE Georgia | <input checked="" type="checkbox"/> SL Sierra Leone |
| <input checked="" type="checkbox"/> GH Ghana | <input checked="" type="checkbox"/> TJ Tajikistan |
| <input checked="" type="checkbox"/> GM Gambia | <input checked="" type="checkbox"/> TM Turkmenistan |
| <input checked="" type="checkbox"/> HR Croatia | <input checked="" type="checkbox"/> TR Turkey |
| <input checked="" type="checkbox"/> HU Hungary | <input checked="" type="checkbox"/> TT Trinidad and Tobago |
| <input checked="" type="checkbox"/> ID Indonesia | <input checked="" type="checkbox"/> UA Ukraine |
| <input checked="" type="checkbox"/> IL Israel | <input checked="" type="checkbox"/> UG Uganda |
| <input checked="" type="checkbox"/> IN India | <input checked="" type="checkbox"/> US United States of America |
| <input checked="" type="checkbox"/> IS Iceland | |
| <input checked="" type="checkbox"/> JP Japan | <input checked="" type="checkbox"/> UZ Uzbekistan |
| <input checked="" type="checkbox"/> KE Kenya | <input checked="" type="checkbox"/> VN Viet Nam |
| <input checked="" type="checkbox"/> KG Kyrgyzstan | <input checked="" type="checkbox"/> YU Yugoslavia |
| <input checked="" type="checkbox"/> KP Democratic People's Republic of Korea | <input checked="" type="checkbox"/> ZA South Africa |
| | <input checked="" type="checkbox"/> ZW Zimbabwe |
| <input checked="" type="checkbox"/> KR Republic of Korea | Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet: |
| <input checked="" type="checkbox"/> KZ Kazakhstan | <input checked="" type="checkbox"/> MA = Morocco <input checked="" type="checkbox"/> Dominica |
| <input checked="" type="checkbox"/> LC Saint Lucia | <input checked="" type="checkbox"/> TZ = Tanzania <input checked="" type="checkbox"/> Costa Rica |
| <input checked="" type="checkbox"/> LK Sri Lanka | |

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. (Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)

Box No. VI PRIORITY CLAIM		<input type="checkbox"/> Further priority claim indicated in the Supplemental Box.		
Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is:		
		national application... country	regional application: regional Office	international application: receiving Office
item (1) 17-05-1999	1999 00685	Denmark		
item (2) 17-06-1999	1999 00864	Denmark		
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office) identified above as item(s):

* Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) (if two or more International Searching Authorities are competent to carry out the International search, indicate the Authority chosen; the two-letter code may be used):

Request to use results of earlier search; reference to that search (if an earlier search has been carried out by or requested from the International Searching Authority):

Date (day/month/year) Number Country (or regional Office)

ISA / EP

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following number of sheets:

request : 4

description (excluding sequence listing part) : 4

claims : 2

abstract : 1

drawings : 2

sequence listing part of description :

Total number of sheets : 13

This international application is accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other (specify):

Figure of the drawings which should accompany the abstract: 2

Language of filing of the international application: English

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

NKT Research A/S

Ole Jagtboe
Patent Manager

For receiving Office use only		2. Drawings: <input type="checkbox"/> received: <input type="checkbox"/> not received:
1. Date of actual receipt of the purported international application:		
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:		
4. Date of timely receipt of the required corrections under PCT Article 11(2):		
5. International Searching Authority (if two or more are competent): ISA /	6. <input type="checkbox"/> Transmittal of search copy delayed until search fee is paid.	

For International Bureau use only
Date of receipt of the record copy by the International Bureau:

PATENT COOPERATION TREATY

10/009227

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT
OR THE DECLARATION

(PCT Rule 44.1)

to:

NKT RESEARCH CENTER A/S,
Attn. JAGTBOE, Ole,
Priorparken 878,
DK-2605, Brøndby
DENMARKDate of mailing
(day/month/year)

20/11/2000

Applicant's or agent's file reference

RESE PA 9902 WO

FOR FURTHER ACTION

See paragraphs 1 and 4 herein

International application No.

PCT/DK 00/00227

International filing date
(day/month/year)

04/05/2000

Applicant

NKT RESEARCH A/S

- 1.
- ☒
- The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

- 2.
- ☐
- The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(3)(a) to that effect is transmitted herewith.

- 3.
- ☐
- With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.☐ no decision has been made yet on the protest: the applicant will be notified as soon as a decision is made.

4. Further action(s): The applicant is reminded of the following:

Shortly after 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.

Within 19 months from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within 20 months from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 18 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority

European Patent Office, P.B. 5618 Patentlaan 2
NL-2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx 31 651 epo nl,
Fax: (+31 70) 840 3018

Authorized officer

Gregory Adan

Form PCT/ISA/220 (July 1998)

EXPRESS MAIL LABEL
NO.: EV 011019060 US

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the letter to be published for the purpose of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 10 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the international bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

- (i) the claim is unchanged;
- (ii) the claim is cancelled;
- (iii) the claim is new;
- (iv) the claim replaces one or more claims as filed;
- (v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/ISA/401).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

KOP1
10/009227From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

To:

JAGTBOE, Ole
LARSEN & BIRKEHOLM A/S
Banegardspladsen 1
P.O. Box 362
1570 COPENHAGEN V
DANEMARK

NOTIFICATION OF TRANSMITTAL OF
INTERNATIONAL PRELIMINARY
EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing
(day/month/year)

1 1. 09. 01

Applicant's or agent's file reference

17503 PCT

IMPORTANT NOTIFICATION

International application No.

PCT/DK 00/ 00227

International filing date (day/month/year)

04/05/2000

Priority date (day/month/year)

17/05/1999

Applicant

NKT RESEARCH A/S

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.
2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.
3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.
4. **REMINDER**
The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/



European Patent Office
D-80298 Munich
Tel. (+49-89) 2399-0, Tx: 523656 epmu d
Fax: (+49-89) 2399-4465

Authorized officer

Paola Ottaviani



PATENT COOPERATION TREATY

PCT

10/009227

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference RESE PA 9902 WD	FOR FURTHER ACTION <small>see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.</small>	
International application No. PCT/DK 00/ 00227	International filing date (day/month/year) 04/05/2000	(Earliest) Priority Date (day/month/year) 17/05/1999
Applicant NKT RESEARCH A/S		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

2. ☐ Certain claims were found unsearchable (See Box I).

3. ☐ Unity of invention is lacking (see Box II).

4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the abstract,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the drawings to be published with the abstract is Figure No.

☒ as suggested by the applicant.

☐ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

2

☐ None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/DK 00/00227

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02H9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01B H01H H02H

Documentation searched other than minimum documentation in the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

FPI-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section EI, Week 198151 Derwent Publications Ltd., London, GB; Class X12, AN 1981-N0515D XP002901245 & SU 009 405 B (KRZHIZHANOV POWER). 8 March 1981 (1981-03-08) abstract	1-14
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 232 (E-765), 29 May 1989 (1989-05-29) & JP 01 039230 A (MITSUBISHI ELECTRIC CORP), 9 February 1989 (1989-02-09) abstract	1-14

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) in which is cited to establish the publication date of another claim or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with this application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Z" document member of the same patent family

Date of the actual completion of the international search

14 September 2000

Date of mailing of the international search report

20. 11. 00

Name and mailing address of the ISA

European Patent Office, P.O. Box 5516 Palantien 2
NL - 2280 HV Rijswijk
Tel.: (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Bertil Nordenberg

INTERNATIONAL SEARCH REPORT

International Publication No

PCT/DK 88/00227

C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DD 126 232 A (INSTITUT, PRÜFFELD FÜR ELEKTRISCHE HOCHLEISTUNGSTECHNIK) 6 July 1977 (1977-07-06) abstract; figures 1-3 ---	1-14
A	DATABASE WPI Section EI, Week 199309 Derwent Publications Ltd., London, GB; Class X12, AN 1993-073656 XPR002901246 & JP 05 022856 A (MITSUBISHI ELECTRIC CORP), 29 January 1993 (1993-01-29) abstract ---	4,12
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 374 (E-808), 18 August 1989 (1989-08-18) & JP 01 126132 A (NIPPON KOWATSU ELECTRIC CO), 18 May 1989 (1989-05-18) abstract ---	5,13
A	WO 96 22258 A (UNIVERSITY OF HAWAII) 25 July 1996 (1996-07-25) page 4, line 3 - line 8 -----	11

INTERNATIONAL SEARCH REPORT

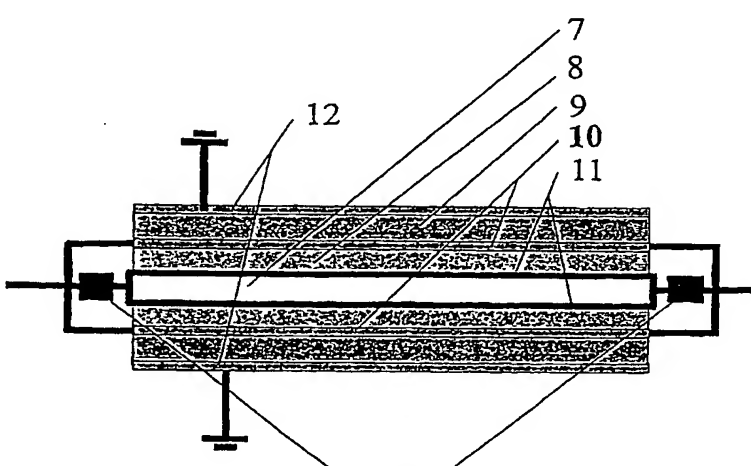
Information on patent family members

International Application No

PCT/DK 00/00227

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
SU 809405	B	08-03-1981	SU 714510 A	07-02-1980
JP 01039230	A	09-02-1989	NONE	
DD 126232	A	06-07-1977	DE 2712990 A	29-12-1977
JP 5022856	A	29-01-1993	NONE	
JP 01126132	A	18-05-1989	NONE	
WD 9622258	A	25-07-1996	US 5591698 A	07-01-1997
			AU 4743796 A	07-08-1996
			EP 0800494 A	15-10-1997
			JP 10511926 T	17-11-1998

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : H01H	A2	(11) International Publication Number: WO 00/70631 (43) International Publication Date: 23 November 2000 (23.11.00)
(21) International Application Number: PCT/DK00/00227 (22) International Filing Date: 4 May 2000 (04.05.00) (30) Priority Data: PA 1999 00685 17 May 1999 (17.05.99) DK PA 1999 00864 17 June 1999 (17.06.99) DK (71) Applicant (for all designated States except US): NKT RESEARCH A/S [DK/DK]; Priorparken 878, DK-2605 Brøndby (DK). (72) Inventors; and (75) Inventors/Applicants (for US only): RASMUSSEN, Claus, Nygaard [DK/DK]; Knivholtvej 16, 1. tv., DK-2720 Vanløse (DK). NIELSEN, Jørgen, Nygård [DK/DK]; Lavendelhaven 75, DK-2830 Virum (DK). ØSTERGAARD, Jens, Jacob [DK/DK]; C. T. Barfodvej 11, 1. tv., DK-2000 Frederiksberg (DK). (74) Agent: NKT RESEARCH A/S; Priorparken 878, DK-2605 Brøndby (DK).		(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), DM, EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>Without international search report and to be republished upon receipt of that report.</i>
(54) Title: A METHOD FOR OVERCURRENT PROTECTION IN A SUPERCONDUCTING CABLE		
		
(57) Abstract <p>By a method and a superconducting cable for overcurrent protection, a current detector comprising a circuit breaker or a current limiter is inserted in series with the superconducting cable, which current detector can be constituted by a superconducting material quenching at a lower current than the cable conductor of the superconducting cable. When the current in the superconducting material gets too high, it is for a short time period fed to a cold shunt that is coupled in parallel with the cable conductors of the superconducting cable. After the short time period, the current is fed to a hot shunt that is coupled in parallel outside the cable conductors of the cable, causing heat dissipation to be effected at room temperature. By use of the method and the cable according to the invention, destruction of the cable is prevented should the superconducting cable lose its superconductivity, e.g. due to cooling failure, whereupon normal operation may soon be resumed without restoration of damages being necessary.</p>		

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

A method for overcurrent protection in a superconducting cable.

The invention relates to a method for overcurrent protection in a superconducting cable.

5

Furthermore, the invention relates to a superconducting cable.

When using superconducting cables in a high-voltage system, it is important that said cables are protected from overcurrents since the result of overcurrents in the cable conductor of a superconducting cable is loss of superconductivity thereof.
10 This means that the cable could soon be exposed to destruction, since the superconducting tapes conducting the current are not at all adapted to transmit large currents, when they are not superconducting.

15 A typical requirement for a superconducting cable is that it should be protected from overcurrents.

This protection requirement may e.g. be that the cable should be able to withstand approximately 40 kA for 1 second.

20 The object of the invention is now to provide a method for protecting a superconducting cable, accommodating the requirements stipulated above.

The objective of the invention is fulfilled by a method of the type defined in the preamble of claim 1, the method being characterized in that a current detector, which
25 can be constituted by a part of or all of the cable, is inserted in series with the cable conductor of the superconducting cable.

Hence, constant monitoring of the current in the superconducting cable during operation is ensured, so that if the current exceeds some predetermined limits, the current will be broken or limited prior to a destructive, heavy heating of the cable.
30

By the insertion, as indicated in claim 2, of at least one superconducting piece as current detector, reliable overcurrent detection is obtained, since the superconducting pieces - if exposed to a current that is too high - exit their superconducting state,
35 causing an intense generation of heat in the superconducting pieces.

This generation of heat can then be used if, as indicated in claim 3, a fuse is inserted as a circuit breaker to break the current to the cable conductors of the superconducting cable.

- 5 With a view to accommodating the time delay in a circuit breaker, specifically the inevitable time delay defined by the period of time necessary for breaking a current by means of a circuit breaker, it is advantageous, as indicated in claim 4, to insert a cold shunt in parallel with the cable conductors of the superconducting cable, the cold shunt being designed to be capable of carrying e.g. 40kA in 0.1 second.

10

For diversion of the current to the superconducting cable after the above-mentioned 0.1 second has elapsed, an electrical conductor is preferably inserted, as indicated in claim 5, in parallel with the cable conductor of the cable and the current detector, said electrical conductor having a higher impedance than the superconducting cable when in its superconducting state.

15

Thus, when the superconducting state ceases, the current is allowed to be diverted in the hot shunt.

Additional appropriate embodiments of the method are set out in claims 6-8.

20

As already mentioned, the invention also relates to a superconducting cable.

This cable is of the type defined in the preamble of claim 9 and is characterised in that the cable conductor of the cable is connected in series with a current detector for detecting overcurrents and a circuit breaker or a current limiter.

25

Appropriate embodiments of the cable are set out in the independent claims 8-14.

In the following, the invention will be discussed in greater detail with reference to an exemplary embodiment shown in the drawings in which:

30

Fig. 1 shows a basic construction of a superconducting cable with overcurrent protection according to the invention,

- 35 Fig. 2 shows a more detailed construction of an embodiment of the cable with overcurrent protection according to the invention,

Fig. 3 shows the relationship with respect to time between currents flowing in the cable according to Fig. 2 in an overcurrent situation, whereas

- 5 Fig. 4 shows in perspective and partially intersected a superconducting cable with overcurrent protection according to the invention.

In Fig. 1 a superconducting cable is denoted by 1, said superconducting cable possibly, as known in the art, being constructed of a core, around which one or more
10 layers of superconducting tapes is/are wound.

Current detectors 3, 4 are coupled to the ends of the cable, the current detectors having built-in circuit breakers or current limiters.

The current detectors may e.g. comprise superconducting pieces such as YBCO or
15 Bi 2212 with built-in circuit breakers, and may be dimensioned such that they quench at a lower current than the superconductor of the actual cable, implying that if the current in the superconducting pieces exceeds a certain value, then the current to the superconducting cable will be broken after a short period of time.

By use of current limiters, the current will naturally be limited.

20 A hot shunt is coupled in parallel with a series connection of the superconducting pieces and the cable conductors of the superconducting cable, said shunt being capable of diverting the current supplied for a short period of time if the current detectors break the current or the current limiter limits the current.

25 Fig. 2 shows a more detailed embodiment of the superconducting cable according to the invention.

In this figure, 13 denotes current detectors corresponding to those denoted by 3 and 4 in Fig. 1.

The reference number 7 denotes a superconducting cable corresponding to the cable 1 of Fig. 1. A cold shunt is provided in parallel with the cable conductors of the cable, the shunt being denoted by the reference number 11. This shunt is cooled to the temperature of the superconductor. On the outside of this cold shunt is a cryostat 8, and on the outside thereof is an electrical insulation 9.
30

On the inside of the electrical insulation 9, an electrical conductor 10 is provided,
35 which is made e.g. of copper and serves as a hot shunt at ambient temperature, cf. below.

The operation of the current detector in the superconducting cable will now be explained in greater detail with reference to the current plot of Fig. 3.

- 5 If it is ascertained that a current, which is too high, is flowing in the superconducting pieces 3, 4 or 13, the current will in a short time period flow in the cold shunt 11.

Then the current will be fed to the hot shunt 10, wherein the current will increase steeply as indicated by the broken line in Fig. 3 at the time 0.1s. At the same time,
10 the current in the cold shunt 11 will decrease steeply.

Damage to the superconducting cable in the event that its superconductivity ceases can thus be avoided, which means that it becomes ohmic and consequently not capable of conducting the usual currents that can be conducted in the superconducting
15 state.

Fig. 4 shows in perspective and partially intersected a superconducting cable as occurring in actual practice, which can be used in connection with the current protection as explained in connection with the preceding figures.
20

In this figure, 12 denotes a shield on the outside of which is a jacket 14. Inside the jacket is a dielectric insulator 15 surrounding an outer steel tube 16.

Inside the steel tube 16, spacers 17 are arranged that are supported by an aluminium foil 18 abutting an inner steel tube 19.

- 25 Inside the inner steel tube 19 a number of superconducting tapes 20 are wound around a hollow core 21.

The cooling of the superconducting tapes can be effected by supplying refrigerant to the channel 22 of the hollow core.

- 30 The reference number 23 denotes the position in which the cold shunt can be placed as explained above, whereas the reference number 24 denotes the position within the dielectric insulator, where the hot shunt can be placed.

Claims:

1. A method for overcurrent protection in a superconducting cable,
5 characterized in that a current detector, which can be constituted by a part of
or all of the cable, is inserted in series with the cable conductor of the
superconducting cable.
2. A method according to claim 1, characterized in that at least one super-
10 conducting piece is inserted as the current detector.
3. A method according to claim 1 or 2, characterized in that a fuse is inserted
as the circuit breaker.
- 15 4. A method according to any of claims 1-3, characterized in that a cold
shunt is inserted in parallel with the cable conductors of the superconducting cable.
5. A method according to any of claims 1-4, characterized in that an electri-
cal conductor is inserted in parallel with the cable conductors of the superconducting
20 cable and the current detector or current limiter, said electrical conductor having a
higher impedance than the superconducting cable when in its superconducting
state.
6. A method according to any of claims 1-6, characterized in that a material
25 comprising a superconducting material quenching at a lower current than the super-
conducting cable is inserted as the current detector.
7. A method according to any of claims 1-6, characterized in that the current
30 detector comprises a relay or a fuse, a thyristor, a transistor, or similar power elec-
tronic components.
8. A method according to any of claims 1-7, characterized in that the current
detector is constituted by a current-dependent resistance.

9. A superconducting cable characterized in that the cable conductors of the cable are connected in series with a current detector for overcurrent detection and a circuit breaker or current limiter.

5 10. A superconducting cable according to claim 9, characterized in that the circuit breaker comprises a fuse.

11. A superconducting cable according to claim 8 or 9, characterized in that the current detector is constituted by a superconducting material such as YBCO or
10 Bi 2212.

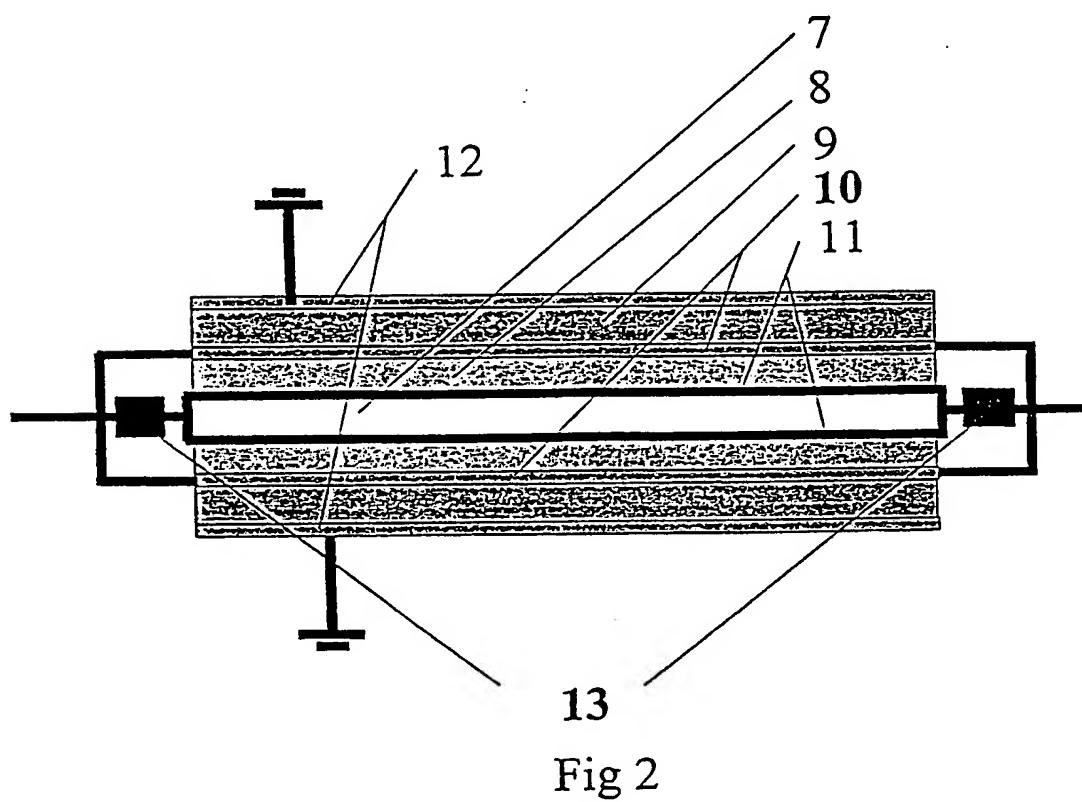
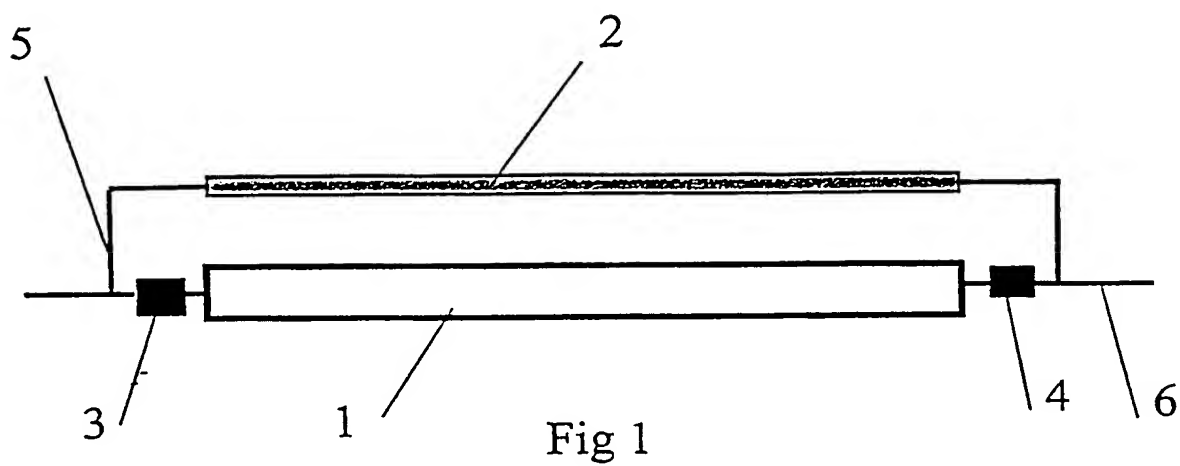
12. A superconducting cable according to any of claims 8-11, characterized in that a cold shunt is coupled in parallel with the cable conductor of the cable. The cold shunt is wound in such a way that the current in this is reduced to a minimum
15 during normal operation.

13. A superconducting cable according to any of claims 10-12, characterized in that a shunt at ambient temperature is coupled in parallel with the superconducting material of the superconducting cable, and the current detector.

20

14. A superconducting cable according to claim 9, characterized in that the circuit breaker comprises high-speed power electronics.

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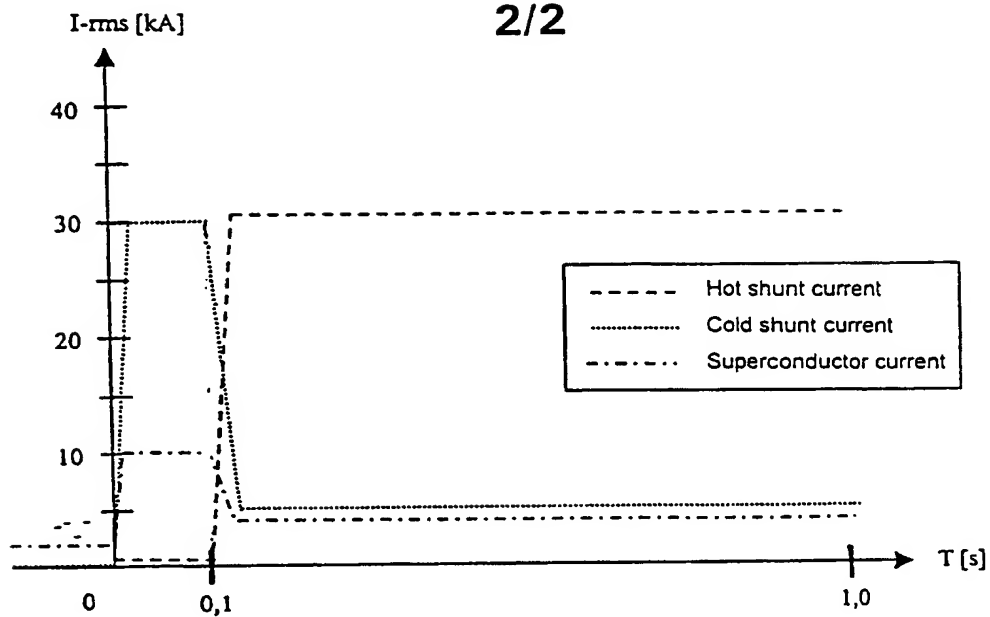


Fig 3

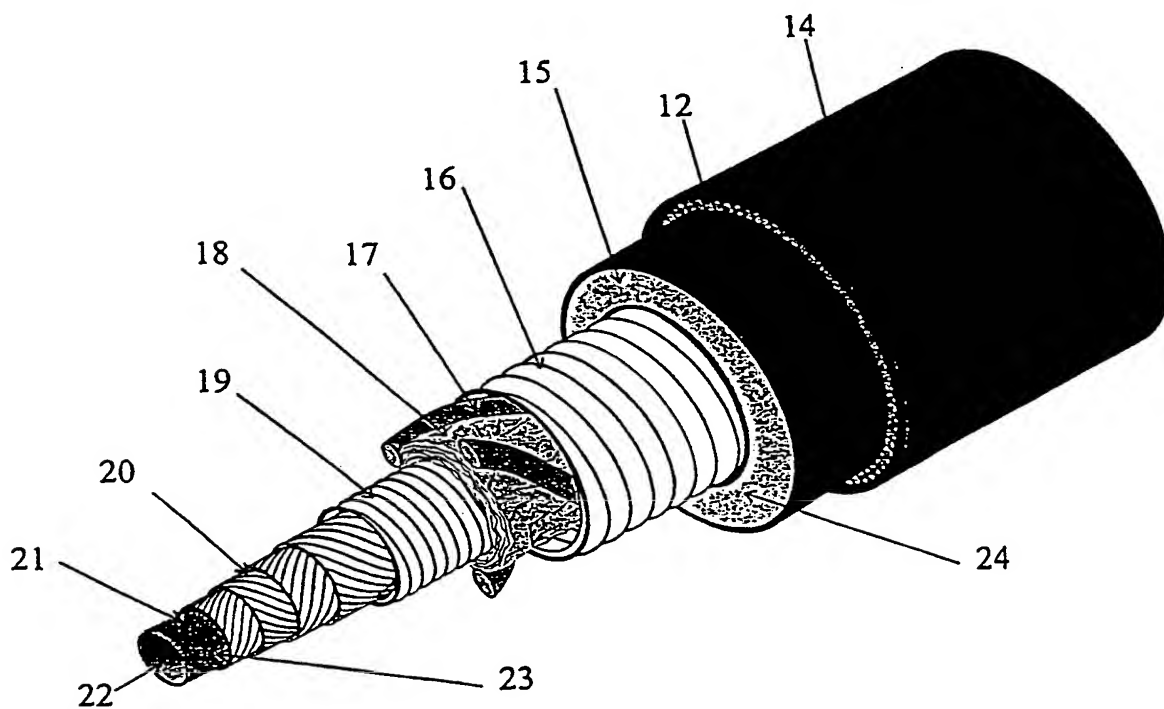


Fig 4

(19) World Intellectual Property Organization
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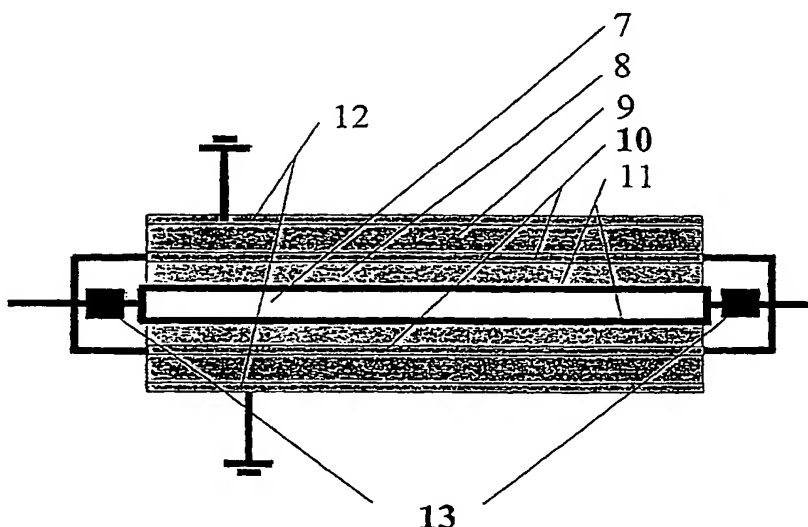
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- Published:
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[Continued on next page]

(54) Title: **A METHOD FOR OVERCURRENT PROTECTION IN A SUPERCONDUCTING CABLE**



(57) Abstract: By a method and a superconducting cable for overcurrent protection, a current detector comprising a circuit breaker or a current limiter is inserted in series with the superconducting cable, which current detector can be constituted by a superconducting material quenching at a lower current than the cable conductor of the superconducting cable. When the current in the superconducting material gets too high, it is for a short time period fed to a cold shunt that is coupled in parallel with the cable conductors of the superconducting cable. After the short time period, the current is fed to a hot shunt that is coupled in parallel outside the cable conductors of the cable, causing heat dissipation to be effected at room temperature. By use of the method and the cable according to the invention, destruction of the cable is prevented should the superconducting cable lose its superconductivity, e.g. due to cooling failure, whereupon normal operation may soon be resumed without restoration of damages being necessary.

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

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